TECHNOLOGICAL PROJECTION AND ADVANCED PRODUCT PLANNING

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INTRODUCTION

This paper has two purposes. The first is to offer a series of refinements to the methodology of technological forecasting. These suggestions are designed to increase the utility of information generated in such forecasts by communicating more fully both the major underlying assumptions and the sensitivity of the resulting projections.

The second purpose is to discuss the steps involved in proceeding from technical feasibility to commercial profitability and to explore the possibilities for linking the techniques of technological projection with those of capital investment analysis and new product planning. Suggestions are also included on areas in which capital investment methodology needs extension and refinement.

Before proceeding with these perhaps rather ambitious objectives, it is important to point out that the primary orientation in the paper is toward use of technological forecasting in development of information for planning and decisionmaking on research and development programs. This interest stems originally from participation in three general trends in defense systems analysis: (1) the growth of a wide variety of weapon system conceptual studies in the late nineteen-fifties, (2) force structure and posture studies in the early and mid-sixties, and (3) recent and current efforts to determine criteria for allocation of support to technology and potential subsystem development projects. Each of these analytic activities now is an important component of technical planning methodology for aerospace research and development and all require meaningful forecasts of technological potential as inputs.

This leads to a second prefatory point: It makes sense, at least in the defense environment, to limit the scope of technological forecasting to projection of technical potential or research opportunities and to treat techniques for analysis of requirements or needs as a separate body of methodology. This distinction can be retained in the commercial realm only up to the point where potential profitability must be assessed, at 'ch point need or demand must be taken into account. In this instance we have attempted to delimit the subject matter by treating only with certain contextual considerations associated with distribution of the product and then move directly to techniques for measuring return on investment. Detailed discussion of a wide range of methods and procedures for economic and market analysis is avoided. Much--but probably not all--of this can be excluded from, or viewed as subsidiary to, a comprehensive methodology for analysis of return on investment in projected new technology.

The final introductory comment is that technological projection is based on the assumption that the overwhelming majority of technological improvements are evolutionary in nature; these build in a more or less orderly fashion on earlier technology; those technological achievements genuinely deserving the label "breakthrough" are rare. There exists, therefore, an underlying rationale to systematic forecasting.

REFINEMENTS IN BASIC METHODOLOGY

Turning to the first major purpose of the paper, it is necessary at the outset to identify those features which we view as inherent in the basic methodology.[*]

Basic Framework and Criteria for Selection of Performance Characteristics

To develop a quantitative projection of potential advance in the state of the art, it is necessary first to select a performance

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[*]These are described more fully in reference 26.

characteristic or combination of characteristics which provides a
satisfactorily comprehensive measure of the state of the art in a given
technical area. This presupposes that actions such as the following
have been taken:

o The breadth or scope of each technical area has been defined
  clearly. Guidelines are needed on the appropriate breadth to
  be used for each of several planning contexts or durations.

o A comprehensive and non-overlapping structure of all major
  technical areas has been developed which details the content
  of each individual area. For most purposes, especially those
  associated with militarily-sponsored research, the technical
  areas as well as the major projects within technical areas
  should be identified, at least to major defense or corporate
  objectives, and perhaps to classes of weaponry proposed to
  meet the more important types of anticipated threats, or to
  product lines designed to capture potential types of markets.

o A system exists for maintaining continuity in the overall
  technical area structure so that any narrowing, branching, or
  other changes can be ide- fied easily on an historical basis.
  This could take the form of a system for maintaining (a) a
  running record of the original plan and its changes and (b)
  a method for tracking progress against the projection.

Assuming that such an overall technical area structure has been
adequately formulated, the search for characteristics suitable for
quantification can then begin in earnest. The following is an illus-
trative list of the types of guidelines or criteria which with further
study might be developed in more precise--hopefully quantitative--
form to serve as an aid in the selection of acceptable measures of
performance capability:

o Comprehensiveness

o Operational Significance

o Ease of Measurement

o Probable Accuracy

o Identification and Measurability of Interdependencies
  o With Other Characteristics
  o With Other Technical Areas

Comprehensiveness. The characteristic or combination of char-
acteristics selected should incorporate a high portion--perhaps some
explicit percentage--of the technical approaches, and quantitatively
identifiable objectives within these approaches, which are likely to
be derived from research in the technical area during the time period
covered by the forecast. A single variable would be preferable if it
can be made to adequately represent progress in the area. As a practical
matter, the number of variables selected usually should not exceed
three or four.

Operational Significance. Preferably the characteristic or
characteristics selected should bear a direct relationship to a spec-
ified need, in the military context to a major design specification
such as those which might appear in future System Operational Require-
ments (SORs). Examples of these are measurements like range, speed,
accuracy, and payload capability.

Ease of Measurement. Consideration should be given to the ease
with which values that are to be shown in the projections can be
measured. Likely sources for such data include research activities
which involve the use of mathematical simulation of the operating
characteristics of the future hardware; partial scale or partial
duration tests, including breadboards and mockups; or full scale and
full duration testing.

Probable Accuracy. Evaluation of this facet might be exercised
using informal checks for reasonableness, formal tests of statistical
validity, or some intermediary means.

Identification and Measurability of Interdependencies. In some
instances a pacing characteristic can be identified and other variables
related to it. This often is difficult, however, since the pacing item
may change as performance levels move from one portion of the range
to another. For example, in aircraft design, propulsion developments--
measured by acceleration or thrust levels-- may be the pacing item at

one part of the speed regime, whereas at higher levels, heat resistant material--measured by temperature--may be the pacing component. This type of interdependent relationship is also identifiable at lower sub-system levels.

In addition to selecting the characteristic or characteristics which will be quantified in the projection, it also may prove useful to provide a brief statement or list of other important characteristics or considerations which should be evaluated qualitatively when assessing a given technical area.

The following are two examples in the hard sciences which use a single performance measure to represent the technical advance. These are taken from impressive work several years ago at Wright Field.[*]
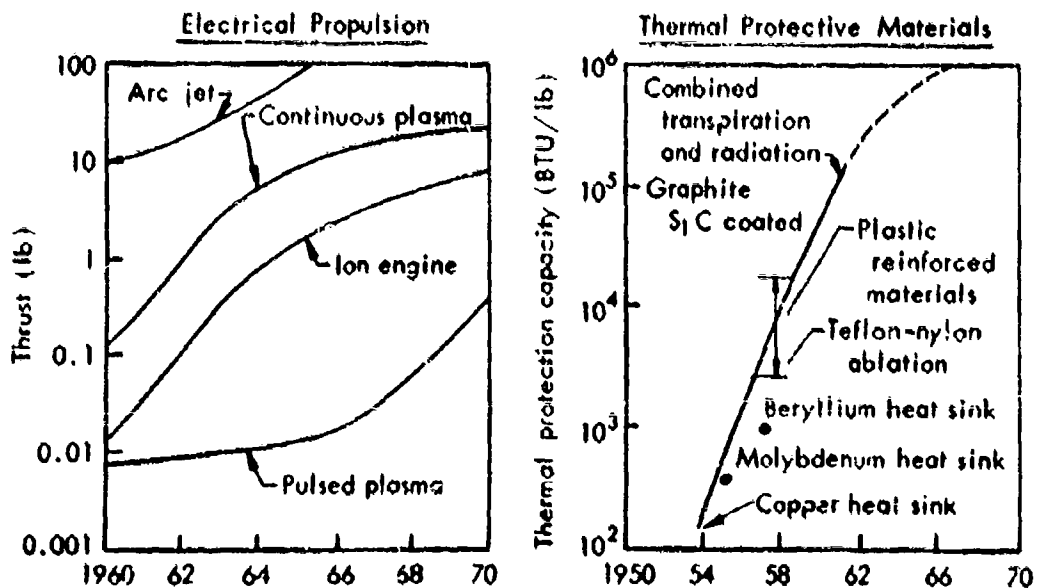

Fig. 1 — First-order technological projections in the "hard" sciences

Obviously there are certain additional difficulties in attempting to select characteristics which can be used for quantitative projection

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[*]See references 17, 18 and 40.

in the soft sciences. It may be that there are some soft science
areas which simply cannot be handled in this fashion. With a little
ingenuity, however, a great deal can be done in attempting to quantify
research in many of these areas.[*] For a project in the life sciences,
for example, one might develop some quantitative measure of knowledge
attained, or success in training a living creature to adapt to increas-
ing duration in an environment of zero gravitational force. Or perhaps
one could demonstrate relaxation under conditions of confinement,
starting with no allowance for change in posture, then limited move-
ment, then limitations of pressurized chambers of increasing dimensions,
10, 20, or 50 feet in diameter. Or one might plot some comprehensive
measure or measures of improvements in the specifications of success-
fully constructed space suits. Admittedly, each of these possibilities
depends to some extent upon identification of the "soft" science
research involved and the eventual hardware required. This need not
always be the case. Assume an example at the other extreme. Although
we are not necessarily recommending it, even in the mathematical
sciences, progress might be forecasted in a quantitative fashion--at
least for the more specific projects. Examples might include the size
and/or complexity of the mathematical programming problem for which a
general solution may be obtained, or a measure of the number of levels,
the flexibility of functional forms, or the number and extent of the
interdependencies which can be handled in projected extensions of de-
composition techniques.

Uniformity in Time Frames and Research Status Points

In forecasting development of performance characteristics with-
in each technical area, it is important that uniformity be obtained
both in the time period covered and the phase of development which is
plotted.

In preparing a series of projections to be used in a given major
planning exercise, one should settle on a standard time period. This

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[*]Such an attempt also may have the advantage of improving the
focus of research within the area, that is, make it a bit "harder" or
more firm and hence more clearly worthy of additional support.

should be maintained throughout the study to measure each technical area. For example:
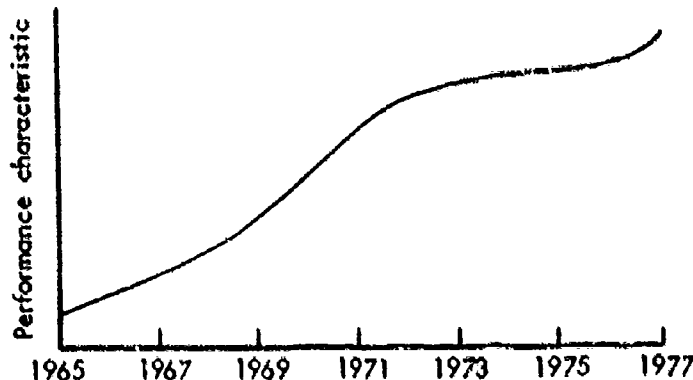

Fig.2—Illustrative standard time period to be used in projections

For closer-in projections it may be desirable to plot anticipated progress for shorter increments of time although to do so may imply greater accuracy than really is possible. In making such a suggestion, the objective is to ensure clarity in the meaning of the projection rather than to imply precision about uncertain technological advances.

In the absence of explicit assumptions, a second source of un-necessary imprecision is misunderstanding of the state to which the level of performance identified actually will have been developed and tested by a given point in time. The plot point might represent an analytic effort indicating that no violation of basic physical law would be required, that first full-scale production would be completed, or any of several intermediary points. In many instances, such a series of points can extend over a period of several years. An illus-trative list from which to select the one or more major events to be plotted, is as follows:

(1) Analysis indicates that no violation of known physical law would be required.

(2) Technical feasibility of new approach proven.

       (2a) By paper studies (mathematical analyses, optimization studies, etc.).

       (2b) By small scale and/or short duration test.

       (2c) By full scale full duration test.

       (2d) By enough full scale, full duration tests to insure an adequate size sample.

(3)   Engineering design of full major subsystem complete.

(4)   Prototype of complete major subsystem thoroughly tested.

(5)   Improvement integrated into total system.

       (5a) On paper.

       (5b) First test completed successfully.

       (5c) Total test series completed successfully.

(6)   Production redesign completed.

(7)   Production facility completed.

(8)   First production units produced at quantity rates ready for delivery.

And as will be discussed subsequently:

(9)   Conversion from technical feasibility to commercial profitability, as either a good or service.

This list may be more lengthy than will be required in a set of guidelines for preparation of technical projections. Its full detail is included here to emphasize the extent of the phases in the development process. In many instances it would be most logical to plot event number 2d in the list; that is, the technical feasibility of the approach has been demonstrated through a statistically adequate program of full-scale tests. At this point the technology is available to the systems engineer for inclusion in new overall system developments. If event 2d is to be used as the standard in a forecasting exercise, obviously any exceptions to this practice must be clearly identified in order that the various projections in an overall package can be meaningful.

Explicit Treatment of Uncertainties

Up to this point, we have furnished a few rudimentary suggestions to aid consistency and uniformity in the basic projections. Current emphasis in adhering to such objectives varies widely but in many

large-scale planning efforts are still only implied rather than spelled out explicitly in forecasting guidelines.

Turning now to the treatment of uncertainty, it is reasonable to assert that attempts to deal with this consideration are handled in an explicit fashion only infrequently. This is not to say that forecasters are unmindful that their function is an uncertain one, but it is to say that preparing forecasts at all is not very widespread and that specifying estimates in terms of high, mid, and low points, confidence limits, or inclusion of qualitative commentary on the probable range accompanying such estimates is a refinement yet to be accomplished. We would urge, however, that not only may it, in fact, be easier for an expert in a given field to prepare such a range than it is to identify a specific single value, but also that confidence in the resulting projection frequently would be considerably enhanced.

A few methods for incorporating such information on uncertainty are provided in the following simple graphs.
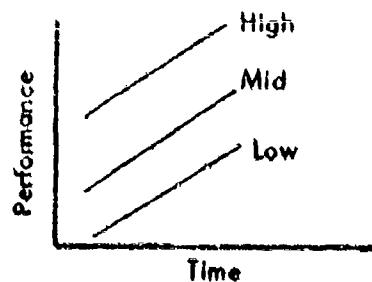

Fig. 3 - Incorporation of High, Mid and Low
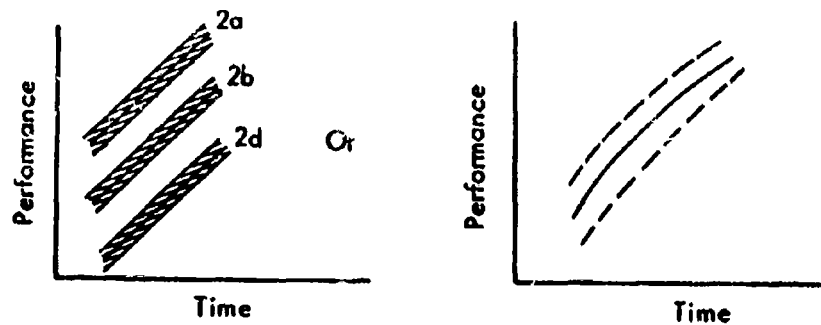Estimates of Progress

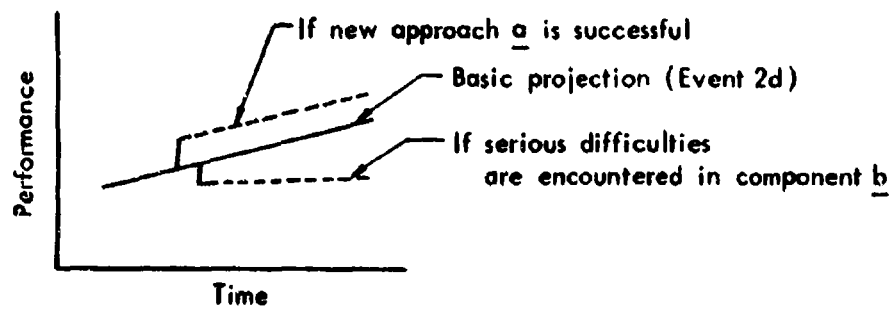Fig. 4 - The Use of Bands or Informal Confidence Limits

Fig. 5 - Identification of Anticipated Results if Selected
Special Circumstances Occur

Such projections also may be accompanied by information which will
provide an additional approximation of the sensitivity of the estimates.
For example,

	Check the appropriate column										
	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	1

(1) Likelihood of

    (a) Meeting the projection, assuming adequate resources are applied.*

    (b) Exceeding the projection by 25%,** (same resource assumption).

    (c) Falling short by 25%,** (same resource assumption)

(2) Probable results if

    (a) The funding were doubled each year over total project life.

               Average percentage increase ____%***

    (b) The funding were cut in one-half over project life.

               Average percentage increase ____%***

    (c) And/or include a statement covering any special benefits which might be obtained either by revising the timing of funding support or by applying additional resources selectively at certain key points during development.

Certainly far more formal probabilistic tools are also available to the forecaster if he is not fearful of the spuriousness in accuracy which they may imply. At present, in the majority of instances, if one is required to make the choice, it probably makes more sense to place major emphasis on developing additional sensitivity ("what if") information

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* Sufficient, but not excessive. Specific interpretation left to the forecaster.

** A substitute percentage may be inserted in cases where 25% is clearly reasonable.

a Values above .5 would indicate either that the basic projection is in error or that an "inadequate" resource application was assumed.

*** Or use a curve, plotting percentage increase by year, if an average value would be misleading.

such as that described below rather than to introduce more elaborate probabilistic refinements.

The Problem of Interdependencies

Of all the methodological issues facing the technological fore-caster, the problem of interdependencies is probably the most vexing. We would not be so naive as to imply that we had anything approaching a full solution to this subject. However, the following discussion and suggestions should help in starting to deal with the issue.

The nature of the interdependency problem can be illustrated in simplified form by the following example taken from the propulsion field. Propulsion systems can be designed for long life or for high accelera-tion. To some extent these two objectives are contradictory, yet in attempting to quantify state-of-the-art advance, it probably is necessary to incorporate both of these variables into the projection. Assume for purposes of illustration that these two characteristics in combination provide a comprehensive measure of the overall potential of the mode of propulsion being examined. It then is necessary to make an assumption similar to one of the following concerning interdependency:

(a)   That time to failure--as a measure of design life-- will remain at current maximum levels and all improvement will take the form of increased acceleration capability, or vice versa;

(b-c)   That design life and acceleration will increase in (b) a constant ratio or (c) other prespecified relationship; or

(d)   That since the need for increased acceleration (or design life) can be justified more substantively than the need for the other capability, therefore performance improve-ments will be dictated by demand. Thus, required increases in acceleration will be plotted first as the dominating characteristic, perhaps including a maximum or plateau at some point. Then assuming this pattern of development of acceleration capability, possibilities for improvement in design life will be estimated.

It is important to recognize both (a) that such projections
probably can be meaningful only within the basic mode of propulsion--
changes in mode may place the projection in a new flight regime[*] --
and (b) that no provision has been made for the possibility of a
genuine breakthrough--reserving this term for very special scientific
advances.   In addition, as already inferred above, any such time-phased
projections are dependent upon the priority and consequent resource
support which is assigned.   Probably the most feasible way to deal with
this interdependency problem is to search out dominant relationships
which can be expressed simply and to ignore lesser interdependencies.

The following are a series of alternate approaches to incorpor-
ate interdependencies into projections, each representing an increasing
level of sophistication:

(1) The use of narrative indicating that the major performance
     characteristics are related but not specifying the precise
     nature of the relationship.

(2) Plotting separately each of the three or four major charac-
     teristics which are interrelated but placing the charts in
     juxtaposition and accompanying them with a set of common
     underlying assumptions.

(3) Selection from a small series of (3 to 10) pre-specified
     forms in which the characteristics might be related.   Vis-
     ualized here are "black box" or "plug-in" relationships
     from which the estimator would choose the one which most
     closely approximates his view of the potential real world
     situation.

(4) Plotting the specific relationships among each set of
     characteristics as best they can be determined.

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[*] It should be noted though that more aggregative projections
frequently can be prepared which summarize individual projections and
encompass a series of successive modes.   Obviously definitional and
classification considerations also are involved in the question of how
great the design change must be to constitute a change in mode.

Approach (3) might be partially accomplished through the use of a simple weighting scheme. For example, if three major variables are involved, reasonable combinations of weights might be:

	Characteristic		
Weight	1	2	3
	1	1	1
	1	1	2
	1	1	3
	1	2	2
	1	2	3
	1	3	3
	2	3	3

This assumes that if any one characteristic is more than three times as important as the others, then it probably should be considered as dominating, and therefore might be used alone to project potential progress.

A complicating, but not insurmountable, consideration would be the circumstance requiring that differing weights for various portions of the range of technical progress be plotted.[*]

ANALYSIS OF THE TRANSITION FROM TECHNICAL FEASIBILITY TO COMMERCIAL PROFITABILITY

Our objective in this section is to establish a linkage between the tools for projection of technological opportunities and the techniques for analyzing potential return on investment--and to do this in a fashion so that the value of each is enhanced. Accomplishment of

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[*]At this point in my earlier paper (P-3181), I included a brief discussion referencing possible methods for coordination of the estimates of a group of experts. Since that time, consensus techniques have been the subject of considerable intellectual activity and a number of interesting papers have appeared or are about to appear. These probably will soon offer substantial refinement in query methodology and such refinements should prove adaptable to the technological forecasting environment. At the moment, however, the "Effort Allocation Guide" work at Wright Field (reference 40) and the efforts of Helmer, et al (references 6, 9, 10) identified in the earlier paper still are as directly addressed to the problem at hand as any of which the author is aware. Portions of three forthcoming RAND Memoranda (references 34, 20, 27) also deal with this subject.

such an objective is no easy task because of the almost unlimited
number of factors which could influence the success or failure of a
new product.

In a sense, analysis of the market environment would seem to be
less difficult than analysis of future international conditions and
their impact on defense requirements. One might argue that economic
trends by comparison are more stable and predictable; that in many--
if not most--business circumstances the time horizon under intensive
analysis is significantly shorter, et cetera. On the other hand, one
might point out that new commercial products are frequently at the
mercy of a fickle or lethargic mass market, while at the same time the
resources available to develop and merchandise the product may by
comparison with defense resources be extremely limited. Hence, at
least from the standpoint of the individual firm, new product ventures
in many respects may be far more uncertain and risky than analysis of
defense requirements.

A Context for Analysis

It was necessary to delimit the field of technological fore-
casting for defense purposes yet a conceptually comprehensive method-
ology for that field was still found to be rather complex. In the
commercial environment it is also imperative to spend adequate time at
the outset in establishing a context for analysis.

Specific Technological Attribute or General Environment Trend.
First, it is important to clarify once and for all whether we are
seeking information on the commercial implications of a specific tech-
nological attribute or set of attributes, or whether initially at least
we are to be more concerned with the environmental trend implications
of a new technology. Both are important and both have been inferred
to be appropriate subject matter for the field of technological fore-
casting. However, tools for the analysis of each may differ signifi-
cantly. In the former instance we are concerned with the specific
profit possibilities of, for example, the increased resistance to heat
of a new material, or the capability of microminiaturizing an electronic

circuit, or, somewhat more specifically, with an increase in acceleration made possible by an improved gear ratio.

Environmental trend forecasting, on the other hand, would be more concerned with the extent and implications of such things as growth of accessible world-wide communications networks; the impact of supersonic transportation on international relations; or of improved contraceptive techniques on population, morals and mores. Such trends may have important economic, social or even political consequences, but the subject matter is delimited somewhat by the fact that in technological forecasting one should logically be concerned only with those trends that are technologically induced. Environmental trend analysis is obviously a fascinating topic; in this paper, however, we devote our primary attention to a methodology for determining more direct implications concerning potential profit stemming from specific technical attributes.

Extent of the Technological Advance. A second factor in establishing the context for analysis of the potential profitability is the extent of the technological advance involved. The impact of such changes can range from very modest improvement in a single physical or performance characteristic to much more dramatic increases in capability, or to completely new types of capability. Further, the advance may extend to a single or a very limited number of uses, or it may exhibit a potential for hundreds or thousands of current and future products. Bracketing the extent of the improvement in some preliminary fashion-- hopefully quantitative--therefore, is exceptionally important before proceeding with subsequent phases of the analysis. In so doing, however, it should not be inferred that small improvements in capability necessarily offer less potential for profit than does larger technical growth. Many commercial products can absorb only modest improvements. But such improvements can often convert an unprofitable article to a highly successful one. Furthermore, dramatic increases in capability may also require sizeable increases in investment and selling price.

Magnitude of Impact on Company. Although this contextual consideration is closely related to the extent of the technological

advance, it is identified separately here to establish clearly the point that a technical advance, even within a firm's general field of activity, may have little or no effect on the company if the firms in the industry are unaware of, or fail to see its potential, or deliberately choose to ignore it. It is important at the outset to develop some preliminary assessment, subject of course to modification, of the magnitude of this impact on the company. Will the advance be a modest modification of a single product, or will it introduce a new product line, even growing to the point of establishing a new division or entire company? In preparing such an evaluation, it is obvious that in many instances, the size of impact is largely a reflection of the extent to which company management chooses to attempt to capitalize on the advance, either in an effort to lead the industry, or in self-defense as protection against competition.

Technical Market or the General Public. Fourth in this series of factors important to identify even before getting down to those considerations associated with the problem of whether the product is "right for us," is the question whether the advance is something likely to be salable in a highly technical market in which major customers are few and can be readily identified, or whether it has potential as a product or products salable in the mass market.

Distribution as Product or Service. Final determination of this consideration in some instances may await more detailed evaluation, but in many cases it is clear that high cost, necessity for special skills or handling, or other reasons, will make it clear at the outset that the new advance stands more chance of achieving profitability as a contributor to a service function. Also, in this instance an innovator may have the option of selling the development as a high cost product to a limited market which will then convert it to a service-- as is done, for example, in jet transport sales; or it may choose to market the services of the equipment it manufactures, as for example, in computer and copying machine rental; or to choose examples where the general public is even more directly involved, an automobile manufacturer may run its own car rental agency, an appliance manufacturer may

operate a coin laundry chain, or a car wash manufacturer may operate
its own equipment.

Lead Time and Timing in the Innovation Process. Another im-
portant factor to be determined at the outset is the time period in
which the product might be introduced. Is it technically feasible
now, or will it be in a year, in five years, or in ten years? Once
such information is estimated or established then one can estimate
other appropriate lead time allowances for administrative approval,
purchase and construction of manufacturing facilities, building of in-
ventory and distribution channels, and obtaining market acceptance.
Other time-related information which should be considered at this
point, is the date when the market might be ready for such a product
or service. Certainly experience has shown that introduction too soon
can be just as devastating as arriving after the competition has already
captured the market or the demand for the product or service has been
exhausted.

Producibility Implications. During the analytic process an in-
tensive engineering and economic evaluation is necessary of the con-
version of a technically feasible accomplishment to a product that can
be "produced at a price." Design simplification without excessive
loss of technical performance, analysis of production methods and rates,
capital and manufacturing costs, all must be assessed. Such factors,
frequently of only tangential interest during development, become
primary during market evaluation. Technological forecasting method-
ology probably has little if anything unique to contribute to the
analysis at this point. Other time-honored methods, in general, will
do very well.*

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*The only specific suggestion we might make is that these tech-
niques frequently are still exercised in a cumbersome and time-consuming
manual fashion, whereas appropriate use of the computer to perform the
extensive routine aspects of this process should not only make it much
faster but should also allow for examination of relevant alternative
production methods. In addition, for the future, automation of many
basic design functions should increase the breadth and depth of such
a simulation and sensitivity testing capability.

Size of Firm and Capital Requirements. I did not want to get involved in a rehash of market analysis checklists and methodology and now I am coming dangerously close. This is not to say that market analysis techniques cannot be improved by such things as increased use of quantification, more comprel: ive lists of considerations, weighting and priority ranking schemes, etc., but rather that technology analysis has to end somewhere. I will, therefore, conclude this contextual discussion by mentioning the need for establishing in a preliminary fashion at the outset whether the magnitude of the investment involved in developing, building the manufacturing capability and waiting out customer acceptance is appropriate to the size of the firm considering the innovation. The failure rate of new enterprises attests to the significance of this factor.

Once this series of considerations have been assessed in a preliminary fashion, then a full scale analysis can be made showing how the potential new product or products relate to the capabilities of the firm, including its long-term objectives, engineering organization, capital plant and equipment and available cash reserves, management and human resources, marketing and distribution channels, complementarity with existing product lines, etc. A checklist summarizing some of these factors, attributed to T. V. Miller at Dewey and Almy Chemical Company, is included as Appendix A. A similar list has been prepared and annotated by John T. O'Meara, Jr. and discussions of similar content are available in a wide variety of texts and articles on market analysis.[*] In addition, several recent developments in quantitative analysis as applied to aerospace problems, for example, "probability of capture" models could perhaps serve to make this analytic process more systematic, but we have chosen not to make their discussion our function here.

Linking With Capital Investment Analysis Methodology--Current and Potential

We move now directly to the final phase of the product analysis process and briefly discuss the problem of measurement of return on

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[*] See reference 24.

investment. In assessing the profitability of a new potential value
for a technical attribute what one really would like to be able to
plot is a curve relating technical performance to return on invest-
ment:

Performance Value of Technical Attribute
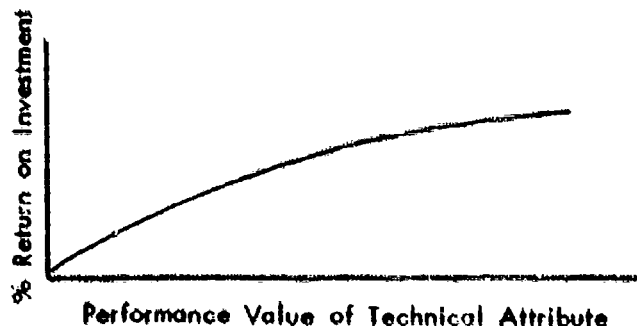
Such curves would be marvelous if they could be made credible.
Theoretically at least, this can be accomplished by systematic spec-
ification of an enormous number of underlying assumptions. In addition,
if enough families of curves are presented, sufficient sensitivity in-
formation should be available to suggest the implications of many of
the more important uncertainties involved. At the moment I am not
really suggesting use of such a curve, however, because the underlying
methodology is not sufficiently well-developed. I would like to discuss
instead several of the more important features of such an underlying
capital investment methodology, both current and proposed. These offer
considerable potential for meaningful linkage with technological pro-
jection techniques, and hence for provision of an integrated and com-
prehensive advanced product analysis methodology. We have all seen
a variety of simple formulae for assessing new products. The follow-
ing is an example:[*]

$$\frac{\text{Chances of Technical Success} \times \text{Chances of Commercial Success} \times \text{Annual Volume} \times \text{Price Less Cost} \times \text{Life}}{\text{Total Costs}} = \text{Product Value Index}$$

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[*]See reference 11.

In addition, payout, average return on average investment, and dis-
counted cash flow or present worth methods, all are described in
numerous references, although the extent of their utilization varies
considerably--particularly the discounted cash flow method.[*] Each of
these methods has its usefulness and certainly is preferable to no
attempt at analysis of the financial implications of a new product.
On the other hand, all of them need improving before they will provide
decisionmakers with the full information required. Building upon the
cash flow method, which is by far the most sophisticated, such ex-
tensions or refinements are of at least four types.

The first of these has already been alluded to in prior remarks
on the necessity for specification of major underlying assumptions.
Widely differing results can be obtained, depending upon the types of
direct manufacturing and overhead costs included; upon depreciation
methods employed; and, especially relevant in this application, upon
the method of write-off used for initial research and development costs.
Assuming that the methods utilized are comprehensive and are applied
consistently, then this problem can be minimized, but most managers
would probably feel more comfortable if these major assumptions were
already identified in analyses of new products. It goes without saying
that basic assumptions regarding quantity, price, production rate,
time-phasing, etc. also should be identified.

The second improvement is easy to describe and frequently more
difficult to handle: the analysis should deal with the total life
cycle of the product. Since, however, both product and capital equip-
ment life are usually unknown, it is necessary to incorporate an es-
timate, which is often really quite arbitrary. The reason for mention-
ing the point is that methods utilized by many firms employ a standard,
often arbitrarily short time period, for example, three to five years.
Such methods implicitly assume equal residual product lifetimes in sit-
uations where such an assumption is patently unrealistic. This would
cause no particular problem if all potential products which met the
minimum criterion were to be funded. But capital resources generally
are limited and to assume equal product lives, in effect, causes the

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[*]For one good description of these techniques see reference 4.

decision to be resolved on the basis of other criteria which may or may not be equally important or as directly relevant.

Only after these two qualifying suggestions have been made on the need for a consistent and comprehensive underlying series of assumptions is it meaningful to consider depicting the financial implications of product life in graphic form similar to that summarily illustrated in the following figure.
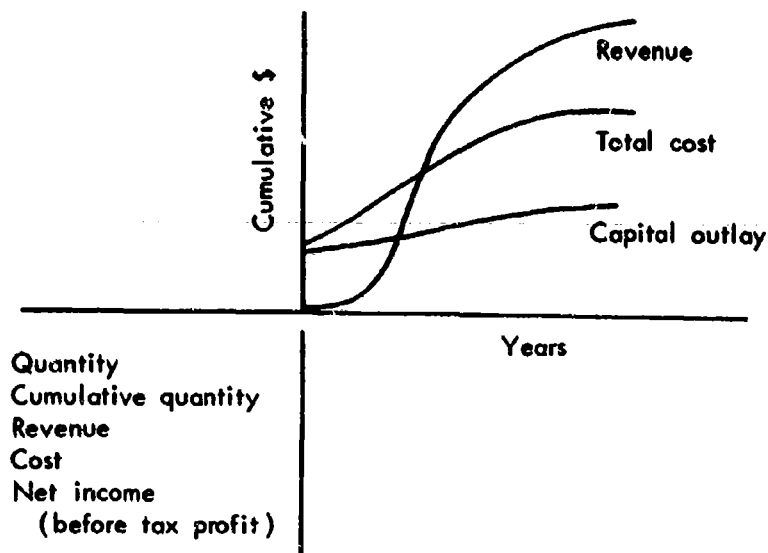

Fig.6—Product life cycle

A second figure (Fig. 7) illustrates in summary form some of the major types of subsidiary financial information necessary in order to construct a meaningful analysis of product cash flow considerations. Significant underlying assumptions identified in this figure but not yet discussed include (a) before- and after-tax comparison, of which the after-corporate income tax is usually the more important;* and

_____

*Profit frequently is also expressed in terms of earnings per share. For new products, in which the major return on investment is expected in future years, average annual, rather than first year earnings per share is the more relevant statistic. New products must be carefully phased into a company's overall product mix to ensure that an adequate earnings level is maintained each year (See Fig. 8 below).

(b) segregation of assets purchased for (and peculiar to) the new
product versus utilization of perhaps otherwise idle assets already
invested by the firm for other special or general purposes.

● Base estimate
  ——.Qty at price——
  ——.Qty at price——
  ——.Qty at price.——
  Revenue
  Mfg cost
    Material
    Labor
    Burden
  Proration of capital cost
    Depreciation, Depletion, Etc.
    Interest
  Corporate income taxes
  After tax profit
  Assets employed
    Purchased for this product
    Fixed
      Equipment
      Facilities
    General
    Fixed
    Inventory
    Accts receivable
    Cash
  Net cash flow
  % Return (D.C.F.R.)
  Factors Bearing on % Return
  (Expressed as +/- % adjustment)
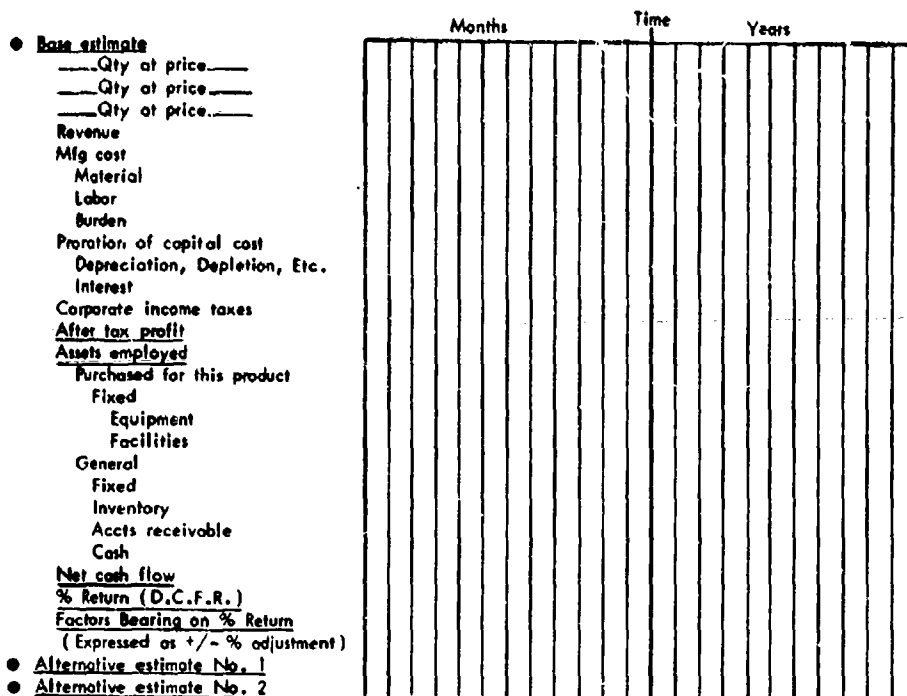● Alternative estimate No. 1
● Alternative estimate No. 2

Fig.7—Analysis of product cash flow (including sensitivity testing)

This figure also illustrates, albeit in a very crude fashion,
the third and in many respects most interesting potential improvement
in capital investment methodology, which should be of considerable use
in assessing the profitability implications of growth values for spe-
cific technical attributes. I refer to the importance of developing
sensitivity information into the basic estimates. This is illustrated
in the figure both (a) by the reference to percentage point adjustments
in the discounted cash flow rate which account for various accounting,
quantity, or perhaps even social contributions, the profitability
implications of which it might be useful to identify explicitly, and

(b) by the provision for alternative estimates in which broader types
of variations--for example, changes in the performance value of the
new technical attribute or attributes--can be shown, Development of a
capital investment simulation capability should make it possible to
provide sensitivity information for several of the more important char-
acteristics or assumptions underlying an estimate of percent return
associated with a given technological growth potential, and which are
responsible for uncertainty in the result. With judicious selection
of the characteristics or assumptions of most interest, such a package
of information could prove of immense value to decisionmakers both in
assessing potential profitability and in bracketing the range of risk
their company should assume.

The fourth and final improvement in investment analysis techniques
is associated with the impact of a new product on product mix and
division or corporate profitability. Figure 8 is of assistance in
illustrating this important consideration. In recent years it has been

	Baseline mix						Mix change No. 1		Mix change No. 2		Etc
	P_1	P_2	P_3	P_4	Etc	Total	Change	Revised Total	Change	Revised Total	
Revenue (Based on __qty at price__)											
Cost											
Cost											
Manufacturing											
Proration of capital cost											
Profit											
Before taxes											
After taxes											
Assets employed											
Product peculiar											
General											
Net cash flow											
% Return (D.C.F.R.)											
Factors bearing on % return											

Extended over a → series of time frames

Fig.8 — Impact on product mix

fashionable to analyze new projects or products in terms of their mar-
ginal contribution to the firm. This type of analysis is useful as
far as it goes, but a series of successive marginal investments with-
out maintenance of a running record of their cumulative impact on total
profitability has led many a firm into serious trouble. Obviously, in
this instance too, sensitivity information on a series of alternative
changes to product mix could prove to be of tremendous value.

SUMMARY

The methodology suggested in this paper has-included several
extensions to basic technological projection techniques, identification
of context in the analysis of the transition from technical feasibility
to commercial profitability, and refinements in capital investment
methodology. If a comprehensive methodology incorporating those various
features can be developed and implemented, then perhaps it will be with
less hesitancy that one might venture to suggest the use of summary
projections directly relating growth in technical attributes with per-
cent return on investment.

Appendix

NEW PRODUCT PLANNING PROFILE

	Very Good	Good	Fair	Poor	Very Poor
I. Stability Factors					
a. Permanence of Market	.	.	.	.	.
b. Possibility of Captive Market	.	.	.	.	.
c. Stability in Depression	.	.	.	.	.
d. Stability in War	.	.	.	.	.
e. Size of Market	.	.	.	.	.
f. How Difficult to Substitute or Copy	.	.	.	.	.
II. Growth Factors					
a. Chance of Substantial Future Growth	.	.	.	.	.
b. Demand Situation or Need for Additional Suppliers	.	.	.	.	.
c. Export Possibilities	.	.	.	.	.
d. Unique Character of Product or Process	.	.	.	.	.
e. Is a Change Going on in this Industry Which This Product Can Ride?	.	.	.	.	.
III. Marketability Factors					
a. Product Does Not Compete with, Imitate or Injure Present Customers	.	.	.	.	.
b. Company's Reputation in Similar Fields	.	.	.	.	.
c. Relation to Markets we Now Sell	.	.	.	.	.
d. Customer's Service Requirements Compared with Company's Ability	.	.	.	.	.
e. Standing in Relation to Probable Competition	.	.	.	.	.
f. Few Variations or Styles Required	.	.	.	.	.
g. Large Volume with Individual Customers	.	.	.	.	.

	Very Good	Good	Fair	Poor	Very Poor

IV. **Financial Factors**

  a. Return on Investment
    1. Fixed Capital
    2. Fixed and Working Capital
    3. Fixed, Working and Initial R&D Cost
  b. Investment Required Relative to Competitive Product
  c. Investment Required Per Dollar of Sales

V. **Position Factors**

  a. Time Required to Become Established and Accepted
  b. Effect on Sales of Other Product Lines
  c. Value Added by our Processing
  d. Chance of Exclusive or Favored Purchasing Position
  e. Raw Materials Improve Vertical Integration
  f. Raw Materials Improve Position in Other Purchases

SOURCE: Adapted from Heyel, Carl (Ed.), _The Encyclopedia of Management_, Reinhold Publishing Corporation, New York, 1963, pp 580-581, and attributed to T. V. Miller, New Product Planning Committee of Dewey and Almy Chemical Company.

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